2D/3D elemental mapping using soft X-ray microscopy

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The x-ray microscopy has been widely accepted as one of the best ways for observing microstructures. The x-ray microscope using synchrotron radiation can observe image by using difference of absorption coefficient of each element. Especially, measurement using two x-ray energies across the absorption edge visualizes distribution of the element. The full-field soft x-ray microscopy at BL-12 has been applied for two-dimensional (2D) and three-dimensional (3D) observation [1, 2]. In this paper, we report light element mapping by using the BL-12 soft x-ray microscope.

Fluorine distribution of sodium fluoride (NaF) was measured to demonstrate the capability of elemental mapping. For 2D observation, the sample was prepared on a Cu mesh with formvar film by deposition of polystyrene latex sphere in NaF solution. This sample was prepared, as a suitable material, as the latex sphere was not containing fluorine which was expected to give absorption contrast of fluorine in NaF environment. The sample for 3D observation was prepared by putting deposited sodium fluoride in the glass capillary tube.

X-ray microscopic images were observed at the two different x-ray energies at 680 eV and 700 eV, below and above the K-absorption edge of fluorine. The difference images were obtained by intensity subtraction between 680 eV and 700 eV images. In the 3D observation, elemental mapping cross-section images were reconstructed from the subtracted images. In these measurements, the magnification was adjusted to 680 and the viewing area is 18 μm × 18 μm. The transmission images for reconstruction were taken with 45 angles each 4 degrees step.

Results of 2D measurements are shown in figure 1. Figure 1(a) and 1(b) show transmission image of NaF by using the x-ray energy at 680 eV and 700 eV respectively. Intensity of images is shown by optical density. The subtracted image, shown in figure 1 (c), is obtained by the subtraction of (b) from (a). Bright structure is observed at area of NaF. On the other hand, dark sphere of c.a. 1 um diameter is observed near the center of NaF crystal. This sphere is ascribed to be polystyrene inside of sodium fluoride, because polystyrene does not contain fluorine.

The result of 3D measurement is shown in figure 2. Figure 2 shows x-ray microscopic images at x-ray energy 680 eV (upper), 700 eV (middle), and subtracted image (lower), respectively. Figure 2(A) and 2(B) are transmission images with projection angle at 0 and 134 degrees, respectively. Some objects like sphere and box appear in the upper, the middle and the lower area of the image. From the subtracted image, the upper and the lower objects contain fluorine. Figures 2(C) and 2(D) are reconstructed cross-section images whose vertical positions are at (a) and (b) in the upper image of figure 2(A). The volume rendering images are shown in figure 2(E) as outline, figure 2(F) as zoomed around (a), and figure 2(G) zoomed around (b). Fluorine distributions are observed as rectangular solid in inside of the capillary tube and as other objects at the inner and outer surface of the capillary tube.

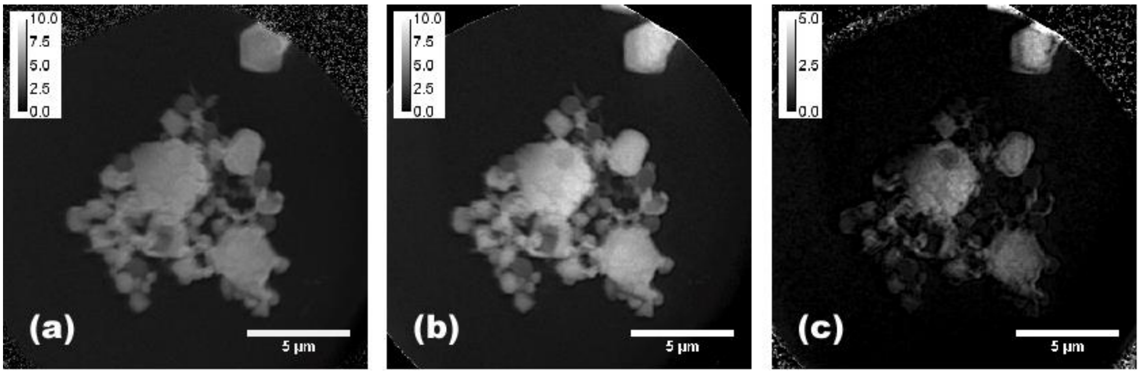

Figure 1 X-ray microscopic images of NaF with polystyrene sphere using x-ray energy at 680 eV (a) and 700 eV (b). The difference image (c) corresponds to fluorine elemental distribution. Magnification is 680. Exposure time is 2 min.

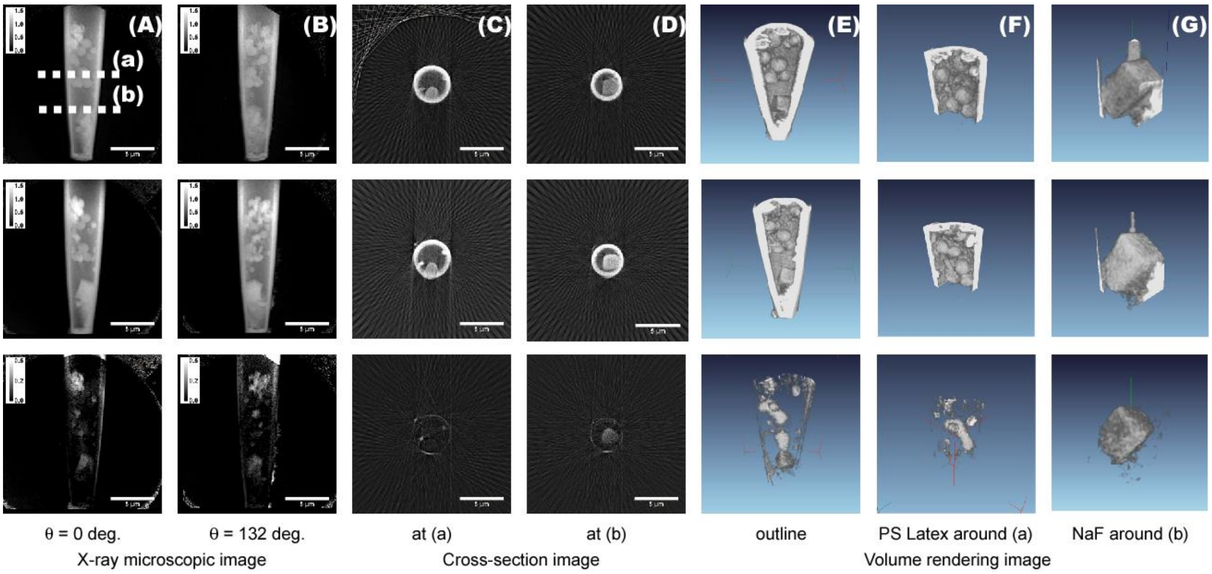

Figure 2 X-ray microscopic images of NaF with polystyrene in capillary tube (A) and (B). Reconstructed cross-section images (C) and (D). Volume rendering images of outline (E), around polystyrene (F), and around NaF crystal (G). The upper and the middle images are taken at x-ray energy of 680 eV and 700 eV, respectively. The lower images are difference images of the upper and the lower images. Magnification is 680. Exposure time is 3 min. The images were taken 45 projections with each 4 degree.

References

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